

APPLICATION NO. 09/826,118

TITLE OF INVENTION: Wavelet Multi-Resolution Waveforms

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Currently amended CLAIMS

APPLICATION NO. 09/829,118

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CLAIMS

WHAT IS CLAIMED IS:

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Claim 1. (~~cancelleddeleted~~)

Claim 2. (~~cancelleddeleted~~)

Claim 3. (~~cancelleddeleted~~)

Claim 4. (~~cancelleddeleted~~)

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Claim 5. (~~cancelleddeleted~~)

Claim 6. (~~cancelleddeleted~~)

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Claim 7. (~~previously presented~~~~currently amended~~) A least-squares method for generating and applying Wavelet waveforms and filters, said method comprising the steps:

said Wavelet is a digital finite impulse response waveform at baseband in the time domain,

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linear phase finite impulse response filter requirements on the passband and stopband performance of the power spectral density are specified by linear quadratic error metrics in the Wavelet,

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Wavelet requirements on the deadband for quadrature mirror filter properties required for perfect reconstruction are specified by a linear quadratic error metric in the Wavelet,

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Wavelet orthogonality requirements for intersymbol interference and adjacent channel interference are specified by non-linear quadratic error metrics in the Wavelet, non-linear quadratic error metrics have quadratic coefficients

dependent on the Wavelet,
Wavelet multi-resolution property requires said error metrics to
be converted to error metrics in the discrete Fourier
transform harmonics of the Wavelet which harmonics are the
5 Wavelet impulse response in the frequency domain,
using a least-squares recursive solution algorithm with quadratic
error metrics, which algorithm requires a means to find the
Wavelet harmonics that minimize the sum of said linear
quadratic error metrics,
10 said harmonics are used to linearize said non-linear quadratic
error metrics,
said least-squares recursive solution algorithm finds the
harmonics which minimize the weighted sum of the linear and
linearized quadratic error metrics,
15 said least-squares recursive solution algorithm starts over again
by using said harmonics to linearize the non-linear error
metrics and to find the corresponding harmonics which
minimize the sum of said linear and linearized quadratic
error metrics,
20 said least-squares recursive solution algorithm continues to be
repeated until the solution converges to the design
harmonics of the Wavelet which is the least-squares error
solution, and
said Wavelet impulse responses in the time domain and
25 frequency domain are implemented in communication systems
for waveforms and filters.

30 Claim 8. (previously presented~~currently amended~~) A second
least-squares method_for generating and applying Wavelet
waveforms and filters, said method comprising the steps:
linear phase filter requirements on the passband and stopband

performance of the power spectral density are specified by linear quadratic error metrics in the Wavelet impulse response in the time domain, using a least-squares recursive solution algorithm

5 with norm-squared error metrics, which algorithm requires a initialization Wavelet and a means to find the Wavelet harmonics which minimize the sum of said linear norm-squared error metrics,

10 said initialization Wavelet is the optimum Wavelet that minimizes the weighted sum of said linear quadratic error metrics which optimum Wavelet is found using an eigenvalue, Remez-Exchange, or other optimization algorithm,

15 said linear quadratic error metrics are transformed into linear norm-squared error metrics in the Wavelet,

15 Wavelet requirements on the deadband for quadrature mirror filter properties required for perfect reconstruction are specified by a linear norm-squared error metric in the Wavelet,

20 Wavelet orthogonality requirements for intersymbol interference and adjacent channel interference are specified by non-linear norm-squared error metrics in the Wavelet,

25 non-linear norm-squared error metrics have norm coefficients dependent on the Wavelet,

25 Wavelet multi-resolution property requires said error metrics to be converted to error metrics in the discrete Fourier transform harmonics of the Wavelet which harmonics are the Wavelet impulse response in the frequency domain,

30 using said least-squares recursive solution algorithm to find the harmonics that minimize the weighted sum of said least-squares linear and non-linear norm-squared error metrics, which harmonics are the design harmonics of the Wavelet least-squares error solution, and

35 said Wavelet impulse responses in the time domain and frequency domain are implemented in communication systems for waveforms and filters.

Claim 9. (~~deleted~~cancelled)

5 Claim 10. (currently amended) A further method of applying
~~Wherein applications of the Wavelet waveforms and filters in of~~
 claims 7 or 8, comprising:

inverse Discrete Fourier Transform (DFT) defines the a mother
Wavelet digital finite impulse response waveform $\psi(n)$ as a
 10 a function of the ~~frequency domain~~ design harmonics ψ_{k_0}
in ~~equation (11)~~ in accordance with:

$$\psi(n) = (1/N') \sum_{k_0} \psi_{k_0} W_N^{k_0 n}$$

15 wherein:

$\psi(n)$ = mother Wavelet time response for index n;

ψ_{k_0} = mother Wavelet frequency response harmonic
for frequency index k_0 ;

20 \sum_n = summation over time index n;

$W_N^{k_0 n} = e^{i2\pi k_0 n / N'}$
= inverse DFT phase rotation for index n length N'
wherein $i = \sqrt{(-1)}$;

25 wherein mother Wavelet refers to a Wavelet at baseband which is
used to generate other Wavelets;

multi-resolution Wavelets $(\psi_{p,q,r}(n) = 2^{-p/2} \psi(2^{-p}n - qM) e^{i2\pi c(p,r)nT})$
~~for scale and translation parameters are defined~~ as a function
of the design harmonics of the mother Wavelet $\psi(n)$ in ~~equation~~

(18) in addition to multi-resolution scale parameters p, q, r according to:

$$\psi_{p,q,r}(n) = (2^{-p/2} / N') \sum_{k_0} \psi_{k_0} W_{N'}^{k_0(n(p)-qM)} e^{i2\pi f_c(p,r)n(p)2^p T}$$

wherein:

- 5 p = multi-resolution traditional Wavelet scale parameter;
 q = multi-resolution traditional Wavelet translation
parameter;
 r = frequency index is a generalization of frequency
index k_0 and identifies the center frequency of the
10 multi-resolution Wavelet at the scale p ;
 $\psi_{p,q,r}(n)$ = multi-resolution Wavelet time response for scale
 p , translation q , frequency index r , at time
index n ;
 M = sampling interval for Wavelet ψ ;
15 $f_c(p,r)$ = center frequency of the frequency translated
mother Wavelet ψ , at scale p and frequency
index r ;
 T = time interval for digital sampling index n ;

- 20 ~~mother Wavelet design harmonics are defined in terms of the~~
~~Wavelet impulse time response digital samples in equation~~
~~(20),~~

- ~~Wavelet design in the frequency domain allows a mother Wavelet to~~
~~be re-scaled for application to multi-channel polyphase~~
25 ~~filter banks by implementing equations (11), (18), (20) which~~
~~derive a multi-resolution Wavelet from a mother Wavelet by~~
~~using the design harmonics of the mother Wavelet and the~~
~~multi-scale parameters of the Wavelet impulse response for~~
~~said application,~~

~~wherein mother Wavelet refers to a Wavelet at baseband which is
used to generate other Wavelets,~~

5 forming a multi-channel polyphase filter bank using a multi-
resolution Wavelet based on the design harmonics of the
mother Wavelet and selection of multi-scale parameters
including one or more traditional Wavelet parameters plus
frequency, spacing, and length wherein:
10 ~~wherein multi-scale parameters are the traditional scale,~~
~~translation, timing parameters, plus frequency, spacing,~~
~~and length parameters of this invention, and wherein~~
~~scale parameter scales time interval between samples,~~
~~sub-sampling, over-sampling, and translation interval~~
15 ~~between Wavelets,~~
~~translation parameter is the timing offset of the Wavelets~~
~~in units of the spacing parameter,~~
~~timing parameter is the digital sampling interval,~~
~~frequency parameter is a frequency offset which translates~~
20 ~~the Wavelet in frequency,~~
~~spacing parameter is the a number of digital samples for~~
~~Wavelet spacing which is equal to the a number of~~
~~channels in a polyphase filter bank with a Nyquist~~
~~sampling rate,~~
25 ~~length parameter specifies the a length of the Wavelet in~~
~~the sampling domain,~~ and
said ~~multi-scale-resolution~~ parameters and the mother Wavelet
design harmonics generate the multi-resolution Wavelet for
the multi-channel polyphase filter bank incorporated in a
30 communications system.

Claim 11. (~~cancelled~~deleted)

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Claim 12. (currently amended) Wherein the method of claim
10, properties of Wavelet waveforms and filters in claims 7 or 8,
further comprising:

~~Discrete Fourier Transform (DFT) defines the mother~~
5 ~~Wavelet in terms of the frequency domain design harmonics in~~
~~equation (11),~~

~~mother Wavelets for scale and translation parameters are defined~~
~~of the design harmonics in equation (18),~~

~~mother Wavelet design harmonics are defined in terms of the~~
10 ~~Wavelet impulse time response digital samples in equation~~
~~(20),~~

~~said Wavelets are multi-resolution Wavelets which enable a~~
~~single Wavelet design at baseband to be used to generate~~
~~Wavelets for multi-resolution applications by implementing~~
15 ~~equations (11), (18) (20) and using the Wavelet design~~
~~harmonics and the multi-scale parameters for the multi-~~
~~resolution Wavelet applications,~~

selecting the design harmonics and multi-resolution parameters so
that said the Wavelet is designed for a communications
20 waveform with no excess bandwidth,

varying the sampling rate in the frequency domain to enable said
the multi-resolution Wavelets are designed to behave like
an accordion in that at different scales the Wavelet is a
stretched or compressed version of the mother Wavelet,

25 said modifying the constraints on the error metrics to enable the
multi-resolution Wavelets to be designed

~~linear waveform and filter least-squares design methods are~~
~~modified to design non-linear Wavelet waveforms for other~~
~~applications including bandwidth efficient modulation and~~
30 ~~synthetic aperture radar, and~~

~~other optimization algorithms exist for generating finding said~~
~~Wavelets.~~